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Final Report 5/7/90

Light Absorption, Attenuation, and Fluorescence in the Planktonic Ecosystem of the North Atlantic: Measurements and Modeling in Support of the Marine Light and Mixed Layer Program.

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Goals

Our long term goal is to understand the biological and optical properties of the planktonic community of the open ocean and to derive mathematical descriptions of this community. We pursue our research goal largely by analyzing bio-optical signals measured in the field and by comparing these signals with the predictions of mathematical models.

Tasks

During this work we developed a macrophotometric technique for measuring the absorption of light by suspended microparticles in sea water. We also developed in collaboration with R. Iturriaga a technique for measuring the absorption efficiency factor for individual cells. During the 4 Biowatt cruises in 1987, we made over 500 measurements of the spectral absorption coefficient of suspended microparticles and developed a statistical technique for determining the contribution by phytoplankton to this coefficient. In addition, we completed a microphotometric analysis of spectral light absorption efficiency by individual particles collected during the Biowatt I cruise. In 1988 we continued our analysis of variability in the spectral absorption coefficient of microparticles in the western Sargasso Sea. The following year we completed the analyses of the data we obtained during the Biowatt field experiment, and described these analyses in a number of papers. The analyses included the development of a statistical method for dividing the spectral absorption coefficient of marine particles into two classes, phytoplankton and detritus, and the development of a technique for calculating the intracellular concentration of chlorophyll a in individual cells from microscopic measurement of the spectral absorption efficiency factor.

Results

The application of microphotometry lead to the following results. Sources of variability in the efficiency factor for absorption by individual phytoplankton in the Sargasso Sea include differences in the concentration and composition of photosynthetic pigments caused by taxonomic differences, as well as differences in adaptation to nutrient and light conditions. We found that the absorption efficiencies of individual phytoplankton cells from field samples increased with depth. These changes were interpreted as a photoadaptive response. Microphotometric estimates of intracellular chlorophyll a showed variability spanning two orders of magnitude, but the mean values compared reasonably for estimates made from cultures of

phytoplankton by other workers. The distribution of chlorophyll a, when compared with particle size, suggests that the optics of pigment packaging may exert a strong selective pressure on cells to optimize the combination of particle size and pigment concentrations.

We also made several discoveries by application of macrophotometery.

First, the cyanobacteria of the genus *Synechococcus* were found to be an important contributor to light absorption at the Biowatt site. The natural populations were rich in phycourobilin and had relatively low concentrations of phycoerythrin. Since phycouroblin absorbs in the blue (495 nm) rather than green (550 nm), the spectral absorption by natural crops of *Synechococcus* is similar to that of the phytoplankton and thus difficult to discern.

Second, a two-component model consisting of phytoplankton and detritus accounted for better than 95% of the observed spectral absorption coefficients for all samples collected within the upper 300m of the water column. Profiles of the two components indicated that there was little variation in the mean absorption coefficient for detritus with depth, but that the amplitude changed seasonally. In contrast, the greatest variability was accounted for by changes in the phytoplankton component, both with depth and seasonally during 1987. This seasonal variation is interpreted in terms of photoadaptation by cells with depth.

Third, we have found in collaborative work with Bidigare (Texas A. & M.) that the contribution by photosynthetic pigments to the absorption coefficients can be assessed by derivative analysis of the spectra. The value of the second and fourth derivatives at specific wavelengths provides a good index of the concentrations of chlorophylls a, b, and c as well as phycourobilin and phycoerythrobilin.

Fourth, we have found in collaborative work with Perry (University of Washington) that the maximum quantum efficiency of photosynthesis by natural crops of phytoplankton and cyanobacteria is not simply determined by dividing the initial slope of a photosynthesis - irradiance curve by the spectral absorption coefficient. The values so obtained are too low because of the large contributions by nonphotosynthetic pigments to light absorption. If corrections for these pigments are made, values for maximum quantum yield are much closer to the values expected from measurements on laboratory cultures. On the other hand, the maximum quantum yields that were calculated for the natural crop appear to vary. This variability may be due to effects of changes in nutrient concentration and light intensity upon the structure of the photosynthetic units in the chloroplast.

Accomplishments

The results summarized above suggests that seasonal variations in spectral absorption by microparticles in the western Sargasso Sea is largely caused by variations in the concentration of two components, phytoplankton and detritus. The seasonal changes in these two components appear to be closely tied to changes in mixed layer depth, surface irradiance, and nutrient concentration. Hopefully, we will soon obtain a better understanding of the factors that determine the concentration of both components. In addition, the measurements made during the Biowatt Program confirm the general validity of our (Kiefer and Mitchell, 1983) formulation of the relationship between light absorption and photosynthesis in the sea.

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